MIMICRY IN THE COLOURS OF INSECTS*

HAVING observed that in treating of the interesting phenomena of mimicry, writers have used indiscriminately very different factors, I shall try to give some preliminary ideas which I do not find published, and which I believe will be useful in explaining this interesting subject.

It will be best to consider the colour and pattern separately. There are three different kinds of colours: viz., colours produced by interference of light, colours of the epidermis, and colours of the hypodermis. All three may either be wanting, or all three or two of them may occur together in the same place.

Colours produced by interference are produced in two different ways: first by thin superposed lamellæ, as in the wings of Diptera, Neuroptera, &c., without any other colour, as in hyaline wings, or connected with other colours as in the scales of Entimus and others.

There must be at least two superposed lamellæ to bring out colours by interference, and there cannot be more than four, as both wings and scales consist only of four layers, two internal belonging to the hypodermis, two external belonging to the epidermis. In fact, if scales taken from dry specimens of Entimus are observed under the microscope, many partly injured can be found, which give different colours according to the layers of the lamellæ which remain.

Secondly, colours by interference are produced by many very fine lines or striæ in very near juxtaposition, as in Apatura and other colour-changing insects. Colours by interference may perhaps be sometimes also produced in the same way as in the feathers of the dove's neck by very small impressions situated near together.

The colours produced by the interference of light are only optical phenomena, differing in this respect from the other colours of the body, the epidermal and hypodermal colours.

The epidermal colours belong to the pigment deposited in the cells of the chitinised external skin, the epidermis. These colours are mostly metallic blue, green, bronze, golden, silver, black, brown, and perhaps more rarely red. The epidermal colours are very easily recognised, because they are persistent, never becoming obliterated or changed after death.

The hypodermal colours are situated in the non-chitinised and soft layer, called hypodermis by Weismann. They are mostly brighter and lighter, light blue or green, yellow, milk white, orange, and all the shades between. The hypodermal colours *in the body* of the insect fade or change, or are obliterated after the death of the insect. A fresh or living insect when opened may easily be deprived of the hypodermal colours simply by the action of a little brush. I said hypodermal colours in the body, because there are hypodermal colours which are better protected, being encased nearly air-tight, and therefore are more easily preserved even after the death of the insect. I refer to the colours in the elytra and wings, and in their appendages, the scales. The elytra and the wings are, as is well known, at first open sacs in communication with the body, of which they are only the extension; of course they are formed of the epidermis and hypodermis, which become so strongly glued together after the transformation into the imago state that a maceration of years tried by me showed no effect at all on such wings. This fact is very interesting, as it explains how wings, and even coloured wings, can be found in palæontological layers in good preservation. The destruction of insects, which is so peculiar to the secondary strata in England, proves, as I believe, that the bodies of the insects must have floated a very long time before they were deposited. It is quite a rarity to find well-preserved insects there, although many well-preserved wings, even of lace-winged flies, have been described.

There is an interval after the transformation, before the membranes of the wings become inseparably glued together; it is at this time that the finishing of the colours takes place. For instance in an Æschna, a *Libellula depressa* or *trimaculata*, if the wing is cut off at the base, the two layers can be easily separated by manipulation under water, and the wing can be inflated with a little tube by separating the borders with a knife. I can show specimens so prepared. But this is only possible as long as the wings possess the appearance of having been dipped into mucilage, an appearance which is well known in young Odonata.

The scales have just the same development as the wings. At first they are little open sacs, communicating with the hollow of the wing and the whole body, and at a later period are glued together like the wings themselves.

In the wings and in the scales the hypodermal colours are formed and finished before the wings stick together, and by this means they are well preserved and safely encased. They have no more communication in the glued parts with the interior of the animal, and are preserved in the same way, as if hermetically inclosed in a glass tube. There are even here in the wings and scales many epidermal colours, chiefly the metallic ones; but all the brighter colours (for instance the somewhat transparent spots in the elytra of the Lampyridæ, Cicindelidæ, &c., and in the greater number of Lepidoptera) are, as I believe, hypodermal colours.

Finally there sometimes occurs outside of the animal, that is, on the epidermis, a kind of colour which I consider as hypodermal colour, such as the pale blue on the abdomen of many Odonata, the white on the outside of many Hemiptera, the pale grey on elytra and thorax of the Goliathus beetle, the powder on Lixus and others. Some of these colours are very easily resolved in ether, and are apparently a kind of wax. I believe that these colours are produced by the hypodermis, and are exuded through the little channels of the pores.

The hypodermal colours are very often different in males and females of the same species, the epidermal colours rarely differ so far as I know; but there are genera with prominent epidermal colours which are nearly always different in different sexes, viz., Calopteryx, Lestes, some Hymenoptera, &c.

It would be interesting to know the different colours of the epidermis in such cases. So far as I know, the change seems to be between related, and not between complementary colours. But my observations are far from having any conclusive importance. The same investigation would be necessary for the hypodermal colours.

The hypodermal colours may change or be altered in some male or female during its lifetime, by sexual or other influences. The epidermal colours never change. By sexual influences yellow is changed into orange, brown into red, and even sometimes more changed. By other influences, for instance by cold in hibernation, pale yellow is changed into red (Chrysopa). The hypodermal colours may be changed even by a voluntary act of the animal, and the new colours disappear again (Cassida). The hypodermal colours are the only ones on which the animal has any influence, either involuntarily by the action of the nutritive fluid, or voluntarily. The epidermal cells are placed entirely outside of any influences of the animal, when once established. It will perhaps be possible to prove that the so-called mimetic colours are all hypodermal colours.

The hypodermal colours seem to be produced by a photographic process (I know no better expression), the epidermal colours by a chemical process of combustion or oxidation. Would it be possible to prove that by a photographic process even the colours of the surrounding world could be transmitted, a great step towards an understanding of the phenomena would be gained. The fact, of course, is very probable, at least, in some instances.

In observing the mimicry, the pattern of an insect must be clearly separated from the colour. In fact, the pattern is not the product of an accidental circumstance, but apparently the product of a certain law, or rather the consequence of certain actions or events in the interior of the animal and in its development. The proof is very easily afforded by the regularity of the pattern in a genus or a family of insects. If studied carefully and comparatively, the pattern in a genus is the same, or is only more or less elaborated. The number of such families is so exceeding great that some example will readily occur to every one.

Moreover a certain and constant pattern can be found for the head, a different pattern for the segments of the thorax, and a different pattern for the segments of the abdomen. This pattern is in the different segments of the abdomen (Hymenoptera, Diptera, Neuroptera, Orthoptera) always the same, only more or less elaborated, and less finished in the first and last segments. In some way the same is true for the thoracic segments.

In some few instances I was able to observe how the pattern is produced. In the Odonata (Dragon-flies) at the moment of transformation the thorax is transparent, and shows no colours at all. At this time the muscles are without importance, and in process of formation. The thoracic muscles, as is well known, are, in the Odonata, very powerful, and also very extraordinary

* Reprinted from the *American Naturalist* for July 1872.

as regards the shape of their tendons. Just along outside the muscles are dark lines more or less well finished, and resulting from the action of the muscles. *Ubi irritatio ibi affluxus*. I believe that it would not be unphilosophical to conclude that a powerful action in the development of the muscles is, in such a case, the cause of a greater combustion or oxidation in the neighbouring parts. In fact, on the head of a Cicada and on the abdomen of an Æschna we find similar patterns, in some way mostly representing the underlying muscles. In the Gomphina the fact is striking, and far more as the stronger species mostly possess a large dark pattern. There are some very small species which are almost entirely yellow; there are no small species entirely black.

Should the fact, with the explanation, be admitted, a step farther in the explanation of the different patterns would be made. I know very well that in the Odonata there are patterns which do not agree with my explanations, even some contrary to it; but if some certain facts be explained, there are perhaps more factors still unknown or unobserved. The explanation for certain facts would still be admissible, or at least not entirely objectionable.*

The patterns on the wings and elytra could not be the product of the action of muscles, but I believe it to be probable that the sudden rush of blood, or even air, by the accelerated circulation and respiration in the act of transformation may have the same effect. In this way some patterns, otherwise not explicable, could be understood. The eyespots in the caterpillars of some Papilionidæ have been ascertained by Leydig to be epidermal colours, and I believe that the various kinds of eyespots in the wings of the imago are also epidermal colours. If a stream of blood meets a small obstacle just in the centre, a funnel is formed; if this obstacle is a ring, and behind it another obstacle, we have two or more funnels, one in the other, and the section of them will be circular or elliptical according to the angle at which they reach the surfaces. Such patterns in the elytra and wings are formed or preformed at the time when the wing is a sac; sometimes before the transformation, and here is another circumstance which explains some patterns. The walls of the sac are suddenly augmented and strongly dilated in the transformation. Small patterns performed in the sac will also be altered and enlarged by the same process, and I know that many patterns of Lepidopterous wings are in such a way very easily explained All the waved lines of the wings and other marks belong here. and as the ribs or nervures seem to grow faster in transformation, the waved appearance would be explained In fact the greater part of the patterns seem to be produced by expansions or distraction of the pattern performed in the wing at some period before the transformation.

H. Hagen

* So far as I know the literature relating to the phenomena of mimicry, all these related differences are often confused, and I believe that in separating them and following the views above given, many facts would be better understood, and this interesting subject more easily advanced.

Besides all the difficulties which oppose a clear and correct view, there is one more which I do not find mentioned, *i.e.* the so-called colour-blindness, and the different degrees of it. Prof. B A. Gould in his excellent work, "Investigations on Anthropological Statistics of American Soldiers," has given attention to it in a very remarkable chapter. Persons who cannot distinguish ripe cherries upon the tree, or strawberries on the vine by their colour, are far more numerous than would be suspected. Serious misunderstandings, and even calamities, have been reported in the army, resulting from mistakes in the colour of green and red light by officers of the signal corps. He gives the statement that usually one in twenty, and in the soldiers examined one in fifty, was subjected to colour-blindness. But these numbers show only the extremes; and it is easy to believe that a much greater number are more or less affected with it. In fact, we have no means of measuring this physiological difference; if two persons call something green, and even compare the colour with certain known objects, there is no proof at all that they see just the same colour. I think that it would be prudent in describing cases of mimicry, especially when they are extraordinary, not to forget that even the best observer may be unaware of this infirmity, and in fact the best authorities on colour-blindness always state that the greater number of persons have no idea of their infirmity.

SCIENTIFIC SERIALS

The *Monthly Microscopical Journal* for October 1872, contains a continuation of Dr. Robert Braithwaite's papers on bog mosses, the present communication being confined to *Sphagnum neglectum* Angstr. Dr. J. J. Woodward contributes a reply to further remarks on Tolles' $\frac{1}{6}$th and Powell and Lealand's $\frac{1}{16}$th. This is succeeded by a communication "On the History, Histological Structure, and Affinities of *Nematophycus Logani* Curr. (*Prototaxites Logani* Dawson), an Alga of Devonian Age," by Wm. Carruthers, F.R.S., in which the author combats the theory advanced by Dr. Dawson, that the fossil in question is coniferous, and contends that it is cryptogamous, belonging to a gigantic alga, of the class *Chlorospermae*. Two plates accompany this very interesting and important communication —"On the active part of the Nerve Fibre, and on the probable nature of the Nerve Current," by Lionel S. Beale, F.R.S., is a further contribution to the researches for which Dr. Lionel Beale has earned a reputation.—"On the Regeneration Hypothesis," by Dr. Louis Elsberg, of New York. The fundamental proposition of this hypothesis is thus stated by its author: "The germ of every derivative living being contains plastitudes of its whole ancestry."—Dr. J. J. Woodward contributes some observations on the use of monochromatic sunlight, as an aid to high-power definition.—A short paper by Prof. Albert H. Tuttle, on one of our common monads is from a communication made to the microscopical section of the Boston Society of Natural History.

Bulletin de l'Académie Royale de Belgique, No. 8. This number contains a mathematical paper of some length, by M. P. Mansion, on singular solutions of differential equations of the first order; also a note by M. Dubois describing some researches on the camphors. He studied the action of pentasulphuret of phosphorus at a high temperature on monobromated camphor, and found that it gave cymol, accompanied with small quantities of hydrocarbons of the same homologous series, and an organic sulphhydrate soluble in alkalies. M. Alphonse Waters gives a sketch of some efforts that were made in Belgium in the middle of the 17th century towards the establishment of free trade.—A note by M. Schuermanns treats of the discovery of objects of amber in Belgium, the writer advising a special study of the circumstances which may have connected Belgium with the commercial route from Etruria to the country of amber, on the Baltic.

SOCIETIES AND ACADEMIES

London

Royal Society, Dec. 5.—"Colouring-matters derived from Aromatic Azodiamines." II. Safranine. By Drs. A. W. Hofmann, F.R.S., and A. Geyger.

Whilst we were engaged with the study of the blue colouring-matters produced by the action of aromatic monamines on azo-diphenyldiamine, our attention became directed to a beautiful red tar-pigment, which has been known for some time by the commercial name of Safranine, being extensively used as a substitute for safflower in dyeing silk and cotton. Safranine has not as yet been minutely examined; but, as far as can be judged from the scanty information we possess regarding its production, it is scarcely doubtful whether this important dye must be looked upon as being the derivative of an azodiamine. The analyses of safranine thus promised to throw considerable light upon the nature of the compounds under examination.

Saframine occurs in commerce either as a solid body or *en pâte*. In the solid state it forms a yellowish-red powder, in which, together with considerable quantities of chalk and common salt, the chlorhydrate of a tinctorial base has been recognised. The pure dye may be easily separated from the crude safranine. It is only necessary to exhaust the commercial product with boiling water; on cooling, the filtrate deposits a slightly crystalline substance, which, after several recrystallisations from boiling water, leaves no residue on ignition. During these operations, however, the salt undergoes perceptible alteration; with every recrystallisation it becomes more soluble and less crystalline. These alterations depend upon the separation of chlorhydric acid from the salt. In fact the percentage of chlorine is found to diminish in the product of succesive crystallisations; thus the product of the third contained 8·48 per cent. that of the fourth crystallisation only 7·46 per cent. Addition of chlorhydric acid to the mother-liquors at once reproduces a crystalline precipitate. This instability of the chlorhydrate, and, in fact, as may even now be stated, of the salts of safranine in general, has very considerably impeded the study of this body, and often materially affected the accuracy of the analytical results. In order to obtain the normal salt, the boiling liquid during the last crystallisation had always to be acidified with chlorhydric acid.

"Synthesis of Aromatic Monamines by Intramolecular Atomic Interchange." By Dr. A. W. Hofmann, F.R.S.

In a paper submitted to the German Chemical Society about a year ago, we proved (Dr. Martius and myself) that the action